PATENT
03466-P0001B WWW/SBS

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	Hans-Wulf Pfeiffer
Application No. 09/929,267	Filing Date: August 14, 2001
Title of Application:	Method Of Increasing The Boundary Layer Strength On Surfaces Of Workpieces Made Of Brittle Hard Materials
Confirmation No. 9985	Art Unit: 1731
Examiner	John Hoffmann

Mail Stop Appeal Brief-Patents
Commissioner for Patents
Post Office Box 1450
Alexandria, VA 22313-1450

Response to Notification of Non-Compliant Appeal Brief

In response to the Notification of Non-Compliant Appeal Brief mailed 25 August 2005, Applicant submits herewith a Substitute Appeal Brief Under 37 C.F.R. §41.37. Entry of the Substitute Appeal Brief is respectfully requested.

Respectfully submitted,

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October 25, 2005

Charlotte E. Hanulik

PATENT
03466-P0001B WWW/SBS

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In Re The Application Of	
Hans-Wulf Pfeiffer	Examiner: John Hoffmann
Serial No.: 09/929,267	Group Art Unit: 1731
Filed: August 14, 2001	
For: Method Of Increasing The Boundary Layer Strength On Surfaces Of Workpieces Made Of Brittle Hard Materials	

Substitute Appeal Brief Under 37 C.F.R. §41.37

Mail Stop Appeal Brief - Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

Having filed herewith a Notice of Appeal from the final rejection of Claims 1-18, all of the claims currently pending, the final rejection being mailed on March 29, 2005, Appellant submits its Appeal Brief for the above-captioned application.

(i) Real Party in Interest

The real party in interest is Fraunhofer-Gesellschaft zur Förderung der Angewandten Forschung residing at Hansastrasse 27c; D-80686 Muenchen, Germany.

(ii) Related Appeals and Interferences

There are no related appeals or interferences.

(iii) Status Of Claims

Claims 1-18 are currently pending, stand rejected and are the subject of the instant Appeal. A copy of each of these claims is attached hereto as Exhibit A.

(iv) Status Of Amendments

There are no pending or unentered Amendments.

(v) Summary Of Claimed Subject Matter

As described in the specification, Appellant discloses and claims a method for increasing the boundary layer strength of a ceramic workpiece. The method comprises the steps of providing a workpiece consisting of ceramic, the temperature of the workpiece not being elevated above room temperature and which does not comprise zirconia. The method further comprises the steps of providing a tool having at least a partially rounded contour with a predetermined diameter, the tool having at least the same order of hardness as the ceramic workpiece. The method

still further the steps of contacting the ceramic workpiece with the tool within a predetermined surface area, the predetermined surface area being less than the total surface area of the ceramic workpiece and selected based upon the composition of the workpiece. The method also includes the steps of producing a plastic deformation on the predetermined surface area, and generating internal compressive strain within the ceramic workpiece in the vicinity of the predetermined surface area. The tool is provided such that the diameter of the tool does not exceed a critical value ranging from about .1 mm to about 4 mm, the critical value depending upon the composition of the ceramic workpiece. The method allows for damage in the form of brittle fracture processes in the predetermined surface area to be substantially avoided and the boundary layer strength of the ceramic workpiece is increased even though the temperature of the workpiece is not elevated above room temperature.

(vi) Grounds Of Rejection To Be Reviewed On Appeal

Claims 1 – 18 stand rejected under 35 U.S.C. §112, first paragraph, as failing to comply with the enablement requirement. Claims 1 – 18 stand rejected under 35 U.S.C. §103 as being unpatentable over U.S. Patent No. 5,128,083 to Brookes ("Brookes") in view of U.S. Patent No. 3,573,023 to Thomas et al. ("Thomas"), further in view of U.S. Patent No. 6,153,023 to Rokutanda et al. ("Rokutanda"), and further in view of the Abstract of JP 04108675 ("the JP Abstract"). Claims 1 – 18 further stand rejected under 35 U.S.C. §103 as being unpatentable over Brookes, Thomas, or JP Abstract in view of U.S. Patent No. 5,228,245 to Rice et al. ("Rice").

(vii) Argument

The Examiner's rejection under 35 U.S.C. § 112, first paragraph is improper because Appellant has addressed each of the issued raised and provided or alternately specifically directed the Examiner's attention to portions of the written specification, which provide the support for the pending claims. The Examiner's rejections under 35 U.S.C. § 103(a) are also improper because neither Brookes, Thomas, Rokutanda, the JP Abstract or Rice discloses, teaches or suggests all of the limitations of independent Claims 1 and 10. For example, Claim 1 requires, in part,

> providing a workpiece consisting of ceramic, <u>the temperature of which is not elevated above room temperature and which does not comprise zirconia</u>,
>
> providing a tool having a diameter that does not exceed a range from about .1 mm to about 4 mm and is at least the same order of hardness as the ceramic workpiece,
>
> contacting the ceramic workpiece with the tool within a predetermined surface area,
>
> generating internal compressive strain within the ceramic workpiece in the vicinity of the predetermined surface area,
>
> wherein <u>generation of damage in the form of brittle fracture processes in the predetermined surface area is substantially avoided</u> and the boundary layer strength of the ceramic workpiece is increased.

(p. 12, Claim 1) (emphasis added). Alternatively, Claim 10 requires, in part,

> contacting the workpiece <u>consisting of ceramic in which, the temperature has not been elevated above room temperature and does not comprise zirconia</u>, with a tool having a predetermined diameter and has at least a partially rounded contour within a predetermined surface area, the tool comprising at least the same order of hardness as the ceramic workpiece, said predetermined surface area being less than the total surface area of the ceramic workpiece and being selected based upon the composition of the workpiece;

> wherein the predetermined diameter for the round contour tool does not exceed a critical value ranging from about .1 mm to about 4 mm, the critical value depending upon the composition of the ceramic workpiece selected such that upon contacting the ceramic workpiece with the round contour tool, <u>generation of damage in the form of brittle fracture processes in the predetermined surface is substantially avoided</u> and the boundary layer strength of the ceramic workpiece is increased.

(p. 13, Claim 10). In fact, the references themselves specifically teach away from the suggested modification and combination. A fair reading of the disclosures of the cited references simply does not disclose or suggest the claimed invention.

Rejection of claims 1-18 under 35 U.S.C. § 112, First Paragraph

The Examiner discussed eight factors in determining whether there is sufficient evidence to support a determination that the disclosure does not satisfy the enablement requirement including:

(A) the breadth of the claims;
(B) the nature of the invention;
(C) the state of the prior art;
(D) the level of one of ordinary skill;
(E) the level of predictability in the art;
(F) the amount of direction provided by the inventor;
(G) the existence of working examples; and
(H) the quantity of experimentation needed to make or use the invention based on the content of the disclosure.

(A) All the claims of the present invention are limited to a workpiece consisting of ceramic. The Examiner however has stated that even though the claims require a workpiece consisting of ceramic that the claims also cover workpieces comprising “ceramets, carbon compsites, etc.” (Official Action 3/29/05, p. 3). The Examiner has further submitted that he “does not agree with applicant's position that the claims are limited to “true ceramics” (whatever that would mean).” *Id.* The Examiner has still further submitted that because the claims are presented

as a method "comprising the steps of" format, that the claims are open to additional steps, which could include the step of "adding a non-ceramic feature thereto, then providing a tool, etc." (Official Action 3/29/05, p. 5). Appellant respectfully disagrees.

Appellant respectfully submits that the claims are limited to workpieces made solely of ceramic (such as silicon nitrides) and do not cover various composite materials as suggested by the Examiner, such as cermets or cemented carbides. *See e.g.* Specification paragraphs 4, 25, and 31. While Claims 1 and 10 both require the limitation of providing a "workpiece consisting of ceramic", the Examiner has ignored the further limitations of Claims 1 and 10, which also require "providing a tool which has . . . the same order of hardness as the <u>ceramic workpiece</u>", "contacting the <u>ceramic workpiece</u> with the tool", "generating internal compressive strain within the <u>ceramic workpiece</u>", and "wherein . . . upon contacting the <u>ceramic workpiece</u> with the tool, generation of damage in the form of brittle fracture processes in the predetermined surface area is substantially avoided and the boundary layer strength of the <u>ceramic workpiece</u> is increased." (emphasis added) All of these steps require use of a <u>ceramic</u> workpiece, which is claimed as a "workpiece consisting of ceramic." There is no opportunity to insert a non-ceramic material insertion step as suggested by the Examiner.

The Examiner has further submitted that he does not know what a "true ceramic" is. (Official Action 3/29/05, p. 3). Appellant respectfully submits that the terms "true ceramics" and "near ceramics" are terms used and understood by those of skill in the art. For example, these terms are used in Thomas where, in differentiating "ceramics" from "near ceramics" Thomas teaches that "we suggest these – materials comprising tungsten carbide, boron carbide, aluminum oxide, or magnesium oxide – to encompass both the near ceramics and the true ceramics." (col. 3, lines 52-55). Thomas further teaches that "the type of material undertaken for

treatment will dictate use of either the basic method of our invention, or the temperature-controlled method of our invention. For the mechanical deformation of materials comprising tungsten carbide can be carried out at normal room temperatures. Materials comprising aluminum oxide, however, require surface deformation in an elevated-temperature environment." (col. 3, lines 58-65). Further clarifying the difference between near ceramics and true ceramics, Thomas itemizes workpieces as follows: "cemented carbides, e.g., tungsten carbide, or boron carbide", and true ceramics "those comprising aluminum oxides, or magnesium oxides."(col. 1, lines 43-45). Appellant therefore respectfully submits that despite the fact that the Examiner does not know what true ceramics are, this term is used by and is well known in industry by those of skill in the art as evidenced the clear usage in Thomas.

Appellant still further notes that as stated in Appellant's declaration, the term "ceramic" "does not include non or near ceramic materials compositions such as for instance, cermets and cemented carbides" (Attached as Exhibit B, Declaration of Mr. Hans Wulf Pfeiffer dated 3/9/04) as suggested by the Examiner. The Examiner arguments appear to ignore the common usage of terms used in industry and simply dismisses Appellant's Declaration as to the breadth of the term "ceramic." However, Appellant respectfully submits that the term ceramic has been clearly defined to exclude "ceramets, carbon compsites, etc." as suggested by the Examiner.

(B) The Examiner has stated that the nature of the invention does not lend itself as evidence to show the invention is enabled. (Official Action 3/29/05, p. 3). Appellant notes that the detailed description discloses specifics relating to the method as claimed including the results from experimentation including for example: par. 25, "an increase of the boundary layer strength of 15% could be achieved"; par. 27, "plastic deformation is restricted to a predetermined laterally narrowly limited surface area"; par. 27, "the tool . . . must be rated as non-sharp-edged"; par. 29,

"critical values for the sphere diameter range from about .1 mm to a maximum of 4 mm"; par. 31, "For determining process parameters required for successful operation preferably two preliminary experiments must be performed: on a plate of the material to be treated the dependence of the compression yielding point and brittle fracture limit on the tool geometry is determined. To this end the static ball thrust test is employed, for instance, which is described e.g. in the article by T. hollstein et al. "Vollkeramische Baelzlager aus Siliziumnitrit: Anwendun, Auslegung und Optimierung" [Fully ceramic rolling bearings made of silicon nitrite: application, designing and optimization], in: VDI-Reports no. 1151, 1995, pages 3 to 10." ("the static ball thrust article") (attached hereto at Exhibit C); par. 31, "A material having at least the same hardness as the workpiece to be treated is selected as tool material" and that the "preliminary experiment furnishes the required tool geometry and the admissible amount of momentum to be introduced."

Accordingly, Appellant respectfully submits that all steps and requirements as claims are described so as to show the invention is enabled.

(C) The Examiner has submitted that the state of the art is that applicant's invention cannot be done. Appellant agrees with the Examiner that the prior art, including that cited by the Examiner against the present claims, has failed to achieve the desired result of increasing the boundary layer strength of workpieces made solely of ceramic without first increasing the temperature of the workpiece substantially above room temperature. Applicant notes however, that the fact that others have not been able to solve this long standing and vexing problem in the industry is not evidence that Appellant's method disclosed and taught in the specification does not achieve the results described therein. Rather, as stated in the specification "[i]t was possible, for instance, to demonstrate that a workpiece made of silicon nitrite could be processed by plastic deformation on its

surface with application of shot-peening methods in such a way that an increase of the boundary layer strength of 15% could be achieved." (par. 25). Appellant has specifically stated the beneficial results that may be obtained in following the steps outlined in the specification. The Examiner appears to simply ignore these results or may simply not believe the submission in the specification. Either case is not evidence that the claimed process will not achieved the specific results taught in the specification.

(F) The Examiner has submitted that the "amount of direction provided by the inventor is low" and that there "is no indication or suggestion as to what ceramics might work or what amount of force is needed to get the strengthening effect." (Official Action 3/29/05 p. 4). Appellant again respectfully disagrees. As stated above in sections (A) and (B), the material of the workpiece is limited to a ceramic and does not include composite materials such as cermets and cemented carbides. In addition, the specification teaches that a "static ball thrust test" is to be employed, referencing the article by T. hollstein et al. "Vollkeramische Baelzlager aus Siliziumnitrit: Anwendun, Auslegung und Optimierung" [Fully ceramic rolling bearings made of silicon nitrite: application, designing and optimization], in: VDI-Reports no. 1151, 1995, pages 3 to 10 (attached hereto at Exhibit C), which is incorporated by reference, which fully outlines and details for performing a "static ball thrust test." The specification further details how the static ball thrust test is to be performed to achieve the desired strengthening results as previously referenced above.

(H) The Examiner has further submitted that the "prior art indicates the invention would not work." (See response to (C) above).

Appellant respectfully submits that static ball thrust tests as taught in the static ball thrust article from 1995 are well known in the art, however, the novel combination of the specific steps taught in the specification provide the "unforseen finding that an increase of the boundary layer strength by mechanical treatment on the surface is possible on brittle, hard materials, without the necessity of elevating the temperature of the brittle, hard material." (par. 25). Accordingly, Appellant respectfully submits that the specification does enable one of ordinary skill in the art to practice and achieve the results disclosed in the specification without undue experimentation.

Argument Regarding All Rejections of claims 1-18 under 35 U.S.C. § 103(a)

All the claims of the present application require, among other steps, providing a workpiece consisting of ceramic, <u>the temperature of which is not elevated above room temperature and which does not comprise zirconia</u>, providing a tool having a diameter that does not exceed a range from about .1 mm to about 4 mm and is at least the same order of hardness as the ceramic workpiece, contacting the ceramic workpiece with the tool within a predetermined surface area, generating internal compressive strain within the ceramic workpiece in the vicinity of the predetermined surface area where generation of damage in the form of brittle fracture processes in the predetermined surface area is substantially avoided and the boundary layer strength of the ceramic workpiece is increased.

The Examiner has submitted that the "language that the workpiece is "consisting of ceramic . . . is met because the relevant references disclose that the item is a ceramic material." (Official Action 3/29/05 p. 5). Appellant admits that Thomas teaches use of true ceramics, however, Thomas fails to teach impacting a true ceramic without first elevating the temperature of the ceramic workpiece.

Thomas specifically teaches that "the type of material undertaken for treatment will dictate use of either the basic method [non-elevated temperature method] of our invention, or the temperature-controlled method [elevated temperature method] of our invention. For the mechanical deformation of materials comprising tungsten carbide [cermets] can be carried out at normal room temperatures. Materials comprising aluminum oxide [ceramics], however, require surface deformation in an elevated-temperature environment." (col. 3, lines 58-65)(emphasis added). Therefore, Appellant agrees with the Examiner that Thomas teaches use of ceramics, however, Thomas specifically teaches that ceramics (i.e. aluminum oxide) must be elevated in temperature prior to treatment.

In differentiating "ceramics" from "near ceramics" Thomas teaches that "we suggest these – materials comprising tungsten carbide, boron carbide, aluminum oxide, or magnesium oxide – to encompass both the near ceramics and the true ceramics." (col. 3, lines 52-55). Thomas further differentiates ceramics from cermets and cemented carbides where it itemizes work pieces comprising "cemented carbides, e.g., tungsten carbide, or boron carbide", and ceramics including "those comprising aluminum oxides, or magnesium oxides." (col. 1, lines 43-45). Therefore, Thomas teaches that the true ceramics (i.e. aluminum oxide, magnesium oxide, etc.) require treatment at an elevated temperature, while the near ceramics also called the cemented carbides (i.e. tungsten carbide, boron carbide) may be treated at room temperature.

It is well settled that if the proposed modification would render the prior art invention being modified unsatisfactory for its intended purpose, then there is no suggestion or motivation to make the proposed modification. *In re Gordon*, 733 F.2d 900, 221 USPQ 1125 (Fed. Cir. 1984). In this case, Thomas directly teaches that the Examiner's proposed modification cannot be done with a ceramic and with the

method taught in Thomas without first elevating the temperature. Accordingly, such a modification of the Thomas method cannot be obvious.

With regard to Brookes, Appellant respectfully submits that the specification describes some general principles of the process stating that "[i]t has been found that the principle variables which have to be controlled during treatment of a hard engineering ceramics material in accordance with the process of the present invention to achieve the benefits ascribed above are as follows: ... 2. The temperature at which the process is carried out must be less than that at which adhesion and seizure would occur between the surface of the hard engineering ceramics material being treated and the second material applying the point/line loading through processes of bulk diffusion yet <u>high enough to enable significant dislocation mobility. This will usually be in the range of 0.3 Tm to 0.5 Tm</u>", where the bottom end (0.3 Tm) is approximately 420°C. (Col. 2, lines 16-20 and 26-33) (emphasis added). Further reading of Brookes points out that certain "principle variables . . . <u>have to be controlled</u>" and that while the temperature may vary, the range is 420°C to 700°C. (emphasis added). Therefore, Brookes also teaches that ceramics must be elevated significantly in temperature prior to mechanical deformation.

Accordingly, no combination of these references can result in a method where a workpiece consisting of ceramic, <u>the temperature of which is not elevated above room temperature and which does not comprise zirconia</u>, may be impacted to increase the boundary layer strength of the ceramic workpiece as required by all of the pending claims.

Rejection of claims 1-18 under 35 U.S.C. §103(a) over Brookes in view of Thomas in view of Rokutanda and further in view of JP Abstract

In view of the above arguments, Appellant further submits that Rokutanda is not directed toward hardening of ceramic workpieces, but rather teaches a method for "projecting shot on the hardened surface of the hard metal product." (Abstract). Rokutanda is not directed toward a method for impacting ceramic workpieces as required by all the pending claims, but rather is directed toward hardening metal products. Therefore, Appellant therefore respectfully submits that Rokutanda cannot be used to teach or suggest impacting a ceramic which is not elevated above room temperature as required by all pending claims.

Likewise, the JP Abstract is entitled "Ceramic-Metal Joined Structure" and is described as a "joined structure of a ceramic component and a metal component." (JP translation provided by Examiner, at p.3). The JP Abstract further states that "[s]ince the ceramics are inherently brittle materials, however, it is difficult to use them alone, and it is more rational to rely on a method wherein a ceramic is used only in a site that must meet a performance requirement base on its combination with another material." (JP translation, p. 4). Therefore, the JP Abstract specifically teaches that a cermet must be used as true ceramics are too brittle. Accordingly, Appellant respectfully submits that Rokutanda cannot be used to teach or suggest impacting a ceramic which is not elevated above room temperature as required by all pending claims.

It is well settled that the mere fact that references can be combined or modified does not render the resultant combination obvious unless the prior art also suggests the desirability of the combination. *In re Mills*, 916 F.2d 680, 16 U.S.P.Q.2d 1430 (Fed. Cir. 1990). In this case, there is no suggestion for combining Rokutanda or the JP Abstract with either Brookes or Thomas as suggested by the

Examiner, but in fact, they teach away from the combination, and therefore an obviousness rejection is inappropriate.

Based on the foregoing, because none of the above-listed prior art teaches, discloses, or suggests, providing a workpiece consisting of ceramic, <u>the temperature of which is not elevated above room temperature and which does not comprise zirconia</u>, providing a tool having a diameter that does not exceed a range from about .1 mm to about 4 mm and is at least the same order of hardness as the ceramic workpiece, contacting the ceramic workpiece with the tool within a predetermined surface area, generating internal compressive strain within the ceramic workpiece in the vicinity of the predetermined surface area where generation of damage in the form of brittle fracture processes in the predetermined surface area is substantially avoided and the boundary layer strength of the ceramic workpiece is increased, as required by the claims, none of the cited references can render any of the claims obvious.

Appellant further respectfully submits that it would not be obvious to further modify Brookes, Thomas, Rokutanda or the JP Abstract to include the limitation of not elevating the ceramic workpiece above room temperature because at least both Brookes and Thomas specifically teach otherwise, while neither Rokutanda nor JP Abstract comment on the use of true ceramics.

Rejection of claims 1-18 under 35 U.S.C. §103(a) over Brookes, Thomas or JP Abstract in view of Rice

In view of the above arguments, Appellant further submits that the Rice specification teaches "[t]ransformation toughening of ceramics is most well known in bodies containing metastable tetragonal zirconia particles" and goes on to teach a method for hardening a ceramic comprising "partially stabilized zirconia (PSZ)" (Col.

1, lines 13-15 & 30-31), or "tetragonal zirconia ... referred to a 'TZP'" (Col. 1, lines 35 and 38-39), or "zirconia-toughened alumina (ZTA)." (Col. 1, lines 44-45.) Additionally, all of the examples listed in the specification of toughening a workpiece include use of zirconia (*See e.g.* Col. 3, lines 39-46 and 62-64; Col. 4 lines 3-7 and 16-17). Accordingly, Appellant respectfully submits that the method taught in Rice includes zirconia in each case and will not work for ceramics at room temperature unless they contain zirconia. Therefore, Rice fails to teach impacting a ceramic that does not comprise zirconia which is not elevated above room temperature as required by all of the pending claims.

Appellant further respectfully submits that it would not be obvious to further modify Brookes, Thomas, the JP Abstract or Rice to include the limitation of not elevating the ceramic workpiece above room temperature because at least both Brookes and Thomas specifically teach otherwise, while the JP Abstract teaches use of a ceramic-metal joined structure rather than only a true ceramic, and Rice specifically teaches that zirconia must be used with ceramic.

Moreover, Appellant respectfully submits that the above-listed references are not properly combined in order to formulate an obviousness rejection. There is no suggestion to combine the cited prior art and in fact, the references themselves teach away from the suggested combination. *In re Mills*, 916 F.2d 680, 16 U.S.P.Q.2d 1430 (Fed. Cir. 1990).

For example, the claims require that the ceramic not comprise zirconia, however, whereas Rice teaches methods that must use zirconia. It cannot be obvious pick and choose specific features or limitations out of various reference to formulate and obviousness type rejection, while at the same time ignoring the primary teachings of the reference itself.

Accordingly, for all of the foregoing reasons, the rejection of claims 1-18 should be reversed. It is respectfully submitted that the cited prior art does not disclose or suggest the claimed invention, and that it would not have been obvious to make the claimed invention. It is respectfully requested that the Examiner be directed to issue a Notice of Allowance as to claims 1-18 of the application.

Respectfully submitted,

October 25, 2005

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EXHIBIT A - Pending Claims

1. (previously presented) A method for increasing a boundary layer strength of a ceramic workpiece comprising the steps of:

providing a workpiece consisting of ceramic, the temperature of which is not elevated above room temperature and which does not comprise zirconia;

providing a tool which has at least a partially rounded contour with a predetermined diameter, the tool comprising at least the same order of hardness as the ceramic workpiece;

contacting the ceramic workpiece with the tool within a predetermined surface area, said predetermined surface area being less than the total surface area of the ceramic workpiece and being selected based upon the composition of the workpiece;

producing a plastic deformation on the predetermined surface area; and

generating internal compressive strain within the ceramic workpiece in the vicinity of the predetermined surface area;

wherein the predetermined diameter for the tool does not exceed a critical value ranging from about .1 mm to about 4 mm, the critical value depending upon the composition of the ceramic workpiece selected such that, upon contacting the ceramic workpiece with the tool, generation of damage in the

form of brittle fracture processes in the predetermined surface area is substantially avoided and the boundary layer strength of the ceramic workpiece is increased.

2. (previously presented) The method of claim 1 wherein the critical value ranges from about .1 mm to about 1 mm.

3. (previously presented) The method of claim 1 wherein the tool has an inherent momentum and is directed onto the ceramic workpiece surface at rest, on which the boundary layer of the ceramic workpiece is deformed by introduction of the momentum of the tool.

4. (previously presented) The method of claim 1 wherein the ceramic workpiece surface is subjected to plastic deformation in a plurality of predetermined surface areas over the surface of the ceramic workpiece by repeated blows of the tool or by the application of a plurality of tools acting upon the ceramic workpiece surface.

5. (previously presented) The method of claim 1 wherein the tool comprises at least one sphere, which is driven onto the ceramic workpiece surface by means of

a blasting installation, operated on compressed air or on an airless blasting means.

6. (previously presented) The method of claim 5 wherein the material of the sphere comprises the same or a similar material as that of the ceramic workpiece to be machined on its surface.

7. (original) The method of claim 1 wherein the tool comprises a hammer.

8. (original) The method of claim 1 wherein the tool comprises a nail.

9. (original) The method of claim 1 wherein the tool comprises a roller.

10. (previously presented) A method of increasing a boundary layer strength of a workpiece consisting of ceramic comprising the steps of:

contacting the workpiece consisting of ceramic in which, the temperature has not been elevated above room temperature and does not comprise zirconia, with a tool having a predetermined diameter and has at least a partially rounded contour within a predetermined surface area, the tool comprising at least the same order of hardness as the ceramic workpiece, said predetermined surface area

being less than the total surface area of the ceramic workpiece and being selected based upon the composition of the workpiece;

wherein the predetermined diameter for the round contour tool does not exceed a critical value ranging from about .1 mm to about 4 mm, the critical value depending upon the composition of the ceramic workpiece selected such that upon contacting the ceramic workpiece with the round contour tool, generation of damage in the form of brittle fracture processes in the predetermined surface is substantially avoided and the boundary layer strength of the ceramic workpiece is increased.

11. (previously presented) The method of claim 10 wherein the critical value ranges from about .1 mm to about 1 mm.

12. (previously presented) The method of claim 10 wherein the tool has an inherent momentum and is directed onto the ceramic workpiece surface at rest, on which the boundary layer of the ceramic workpiece is deformed by introduction of the momentum of the tool.

13. (previously presented) The method of claim 10 wherein the ceramic workpiece surface is subjected to plastic deformation in a plurality of

predetermined surface areas over the surface of the ceramic workpiece by repeated blows of the tool or by the application of a plurality of tools acting upon the ceramic workpiece surface.

14. (previously presented) The method of claim 10 wherein the tool comprises at least one sphere, which is driven onto the ceramic workpiece surface by means of a blasting installation, operated on compressed air or on an airless blasting means.

15. (previously presented) The method of claim 14 wherein the material of the sphere comprises the same or a similar material as that of the ceramic workpiece to be machined on its surface.

16. (original) The method of claim 10 wherein the tool comprises a hammer.

17. (original) The method of claim 10 wherein the tool comprises a nail.

18. (original) The method of claim 10 wherein the tool comprises a roller.

19. (cancelled)

EXHIBIT B – Declaration of Mr. Hans-Wulf Pfeiffer

See attached sheets.

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	Hans-Wulf Pfeiffer
Serial No. 09/929,267	Filing Date: August 14, 2001
Title of Application:	Method Of Increasing The Boundary Layer Strength On Surfaces Of Workpieces Made Of Brittle Hard Materials
Confirmation No. 9985	Art Unit: 1731
Examiner	Christopher Fiorella

Mail Stop Non-Fee Amendment
Commissioner for Patents
Post Office Box 1450
Alexandria, VA 22313-1450

Declaration of Mr. Hans Wulf Pfeiffer (37 CRF §1.132)

I hereby declare and state as follows:

1. I, Mr. Hans Wulf Pfieffer, am the inventor of patent application serial no. 09/929,267. A copy of my curriculum vitae is attached hereto in support of this Declaration.

2. I have extensive experience and have performed extensive experimentation involving the device described in my patent application serial no. 09/929,267 relating to ceramic engineering materials.

Mailing Certificate: I hereby certify that this correspondence is today being deposited with the U.S. Postal Service as *First Class Mail* in an envelope addressed to: Commissioner for Patents and Trademarks; Post Office Box 1450; Alexandria, VA 22313-1450.

March 22, 2004

Charlotte E. Hanulik
Charlotte E. Hanulik

3. Based upon my years of experience and being one of ordinary skill in the art in methods of increasing boundary layer strengths on surfaces of workpieces made of brittle hard materials, I understand and one of ordinary skill in the art would understand the term "ceramic" to include only true ceramic materials and does not include non or near ceramic materials compositions such as for instance, cermets and cemented carbides.

4. As one of ordinary skill in the art reading U.S. Patent No. 3,573,023 ("the '023 patent") to Thomas et al., I understand the '023 patent to teach that while cermets and cemented carbides may be hardened by a force applied to a workpiece at room temperature, the temperature of ceramics on the other hand must be elevated substantially above room temperature prior to the application of a force to harden the workpiece.

5. I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

March ~~February~~ 09, 2004

Hans-Wulf Pfeiffer
Mr. Hans Wulf Pfieffer

EXHIBIT C – T. Hollstein et al. Article entitled "Volikeramische Baelzlager aus Siliziumnitrit: Anwendung, Auslegung und Optimierung"

See attached sheets.

Vollkeramische Wälzlager aus Siliciumnitrid: Anwendung, Auslegung und Optimierung

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1. Vollkeramische Wälzlager

Die Forderung nach größtmöglicher Prozeßsicherheit bei verfahrenstechnischen Anlagen und der steigende Kostendruck in den Bereichen Wartung, Instandhaltung und Neubeschaffung von Anlagekomponenten sind der Hauptgrund für die gewachsenen Anforderungen an die Lagertechnik, beispielsweise in Rührwerken und Pumpen. Da Pumpen über einen weiten Temperaturbereich einsetzbar sein sollen und da Schmierstoffe, die zu Verunreinigungen führen können, vermieden werden müssen, ergeben sich neben der Forderung nach langer Lebensdauer und günstigem Kosten-Leistungs-Verhältnis zusätzliche Anforderungen hinsichtlich der Trockenlaufeignung und der Medienschmierung.

Keramische Werkstoffe, insbesondere das in vollkeramischen Lagern verwendete Siliciumnitrid, ermöglichen die Herstellung von Lagern, welche diesen Anforderungen gerecht werden. Die hohe Korrosionsbeständigkeit, die nur in Ausnahmefällen, wie beispielsweise in Flußsäure und in schwerem Wasser bei 300°C, den Einflüssen des Mediums nicht standhält, ermöglicht den Einsatz mediengeschmierter Lager /1/. Da vollkeramische Lager auch im Trockenlauf nicht katastrophal verschleißen, können sie z.B. in Tauchpumpen eingesetzt werden. Die Hochtemperaturbeständigkeit der Keramik ermöglicht darüber hinaus den Einsatz der Lager unter Bedingungen, die metallischen Lagern verschlossen bleiben.

Für keramische Wälzlager existieren derzeit keine Auslegungskriterien. Da es sich beim vollkeramischen Wälzlager um ein im Vergleich zu den metallischen Lagern "junges" Bauteil handelt, wird es noch einige Jahre dauern, bis verläßliche Kriterien zur Dimensionierung der Lager entwickelt sind. Bis dahin werden die Lager konservativ ausgelegt, so daß zum einen zwar das Versagen im Betrieb vermieden wird, jedoch die Möglichkeiten des Werkstoffes bei weitem nicht ausgenutzt werden. Ziel der vorgestellten Arbeiten ist, Aussagen zum Tragfähigkeitsverhalten im statischen und im rollenden Lastfall zu machen. In un- oder mangelgeschmierten Betriebszuständen, also bei einer maximalen Beanspruchung, wird eben der Möglichkeit des sofortigen Versagens auch das zeitabhängige Versagensverhalten im Wälzverschleiß unter lagertypischen Belastungsbedingungen untersucht.

2. Experimentelle Untersuchungen

2.1 Werkstoff

Für Wälzlager aus Hochleistungskeramik werden im allgemeinen gasdruckgesinterte (GPSN) oder heißisostatisch gepreßte (HIPSN) Siliciumnitride verwendet. Werkstoffdaten für eine gasdruckgesinterte Qualität sind in Tabelle 1 angegeben, das Gefüge ist in Bild 1 gezeigt. Diese Werkstoffqualität wurde für die Platten- und Laufringversuche benutzt. Die Kugeln (Durchmesser von 4,76 mm bis 12,4 mm) waren dagegen aus HIPSN.

charakt. Festigkeit σ_0	900 MPa
Weibullmodul m	18
Elastizitätsmodul E	300 GPa
Poissonzahl ν	0,28
Rißzähigkeit (Vickersmethode)	7,5 MPa$\sqrt{m}$
Rißzähigkeit (Brückenmethode)	4,2 MPa$\sqrt{m}$

Tabelle 1: Werkstoffdaten SN-N3208, RT (Hersteller Cremer Forschungsinstitut, CFI)

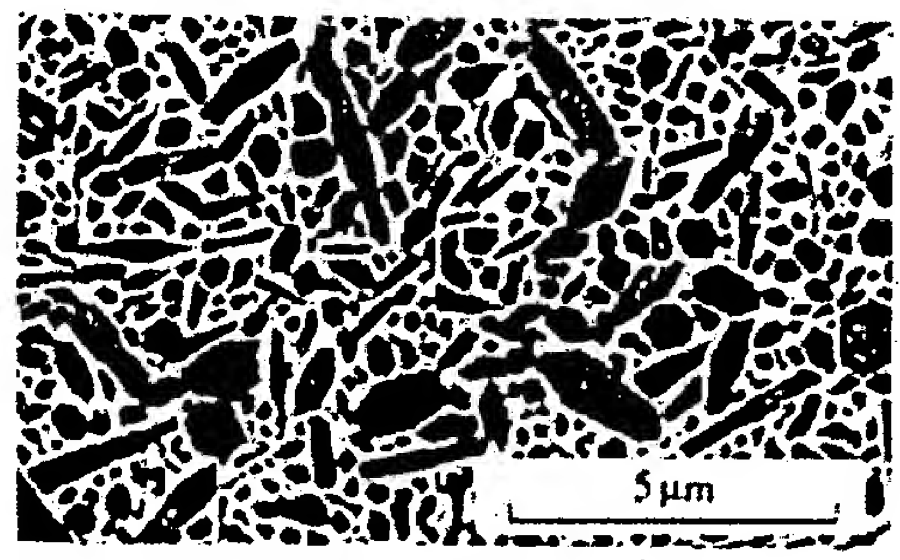

Bild 1: Gefüge SN-N3208

2.2 Statischer und gleitender Kugel-Platte-Versuch

Im statischen Lastfall kann die Tragfähigkeit durch Kugeldruckversuche ermittelt werden. Bei solchen Versuchen können infolge der hohen Hertzschen Pressung sowohl plastische Verformung als auch Rißbildung auftreten. So haben Kugeldruckversuche mit polierten Platten gezeigt, daß bei Kugeln mit Radien kleiner als 4 mm in den Platten erst plastische Verformung und dann Rißbildung auftritt, während bei Kugelradien größer als 4 mm erst Rißbildung, gefolgt von plastischer Verformung auftritt /2/. Diese Zusammenhänge sind in Bild 2 dargestellt. Die für das erste Auftreten plastischer Verformung notwendigen Kräfte F_{plast} hängen vom Quadrat des Kugelradius R ab. Unter Annahme des Hertzschen Spannungsfeldes und der von Mises Fließbedingung ergibt sich:

$$F_{plast} = \frac{2\left(1-\nu^2\right)\left(1{,}6Y\pi\right)^3}{3E^2}R^2 \qquad (1)$$

Die Anpassung dieser Gleichung an die experimentell bestimmten $F_{plast}(R)$ ergibt eine Fließspannung Y von 6790 MPa. Werden Kraft-Verschiebungskurven für das Kugel-Platte-System mit der Methode der Finiten Elemente modelliert /2/, so ergibt sich, in guter Übereinstimmung zum hier vorgestellten Ergebnis, eine Fließspannung von 6300 MPa.

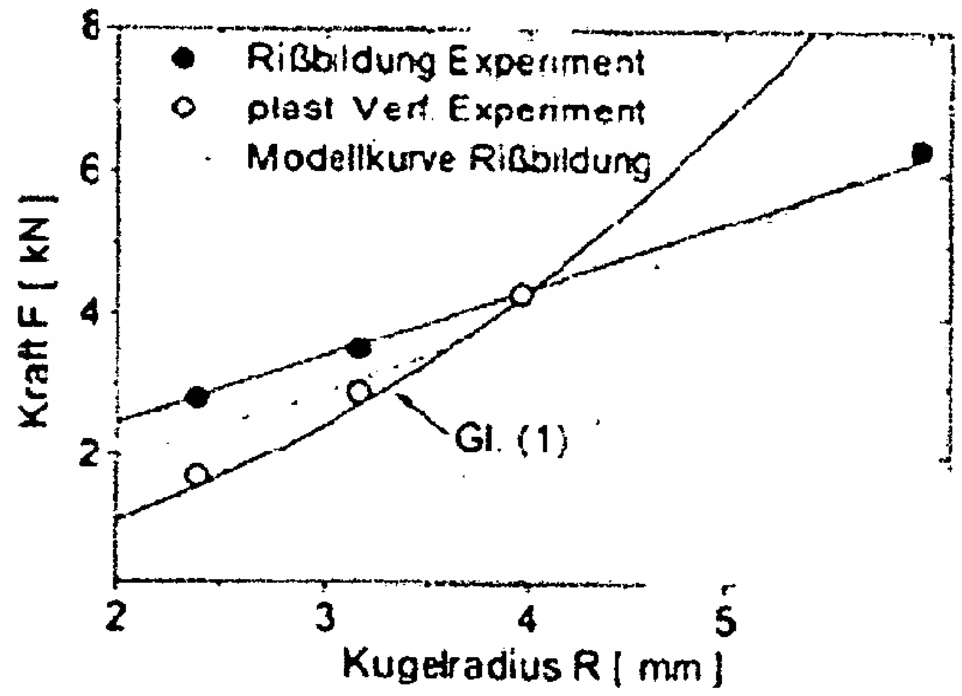

Bild 2: Druckkraft für Rißbildung und plastische Verformung als Funktion des Kugelradius

Im Kugel-Laufring-Experiment wird zur experimentellen Untersuchung der statischen Tragfähigkeit ein Außenlaufringsegment mit einer Lagerkugel bis zur Rißbildung belastet. Die untersuchten Lagersegmente erreichen in den statischen Experimenten eine Tragfähigkeit von ca. 7,5 GPa. Nach der Rißbildung werden die Laufringsegmente außerhalb der Prüfvorrichtung gebrochen, so daß der Tiefenverlauf der Risse deutlich erkennbar wird (Bild 3). Während bei planparallelen Platten im Kugeldruckversuch wegen der am Rande der Kontaktzone hohen Zugspannungen Konusrisse auftreten, bilden sich im Kugel-Laufring-Kontakt Risse nur an den schmalen Enden der Kontaktellipse (Bild 3). Dort treten entsprechend der Spannungsanalyse die höchsten Zugspannungen auf.

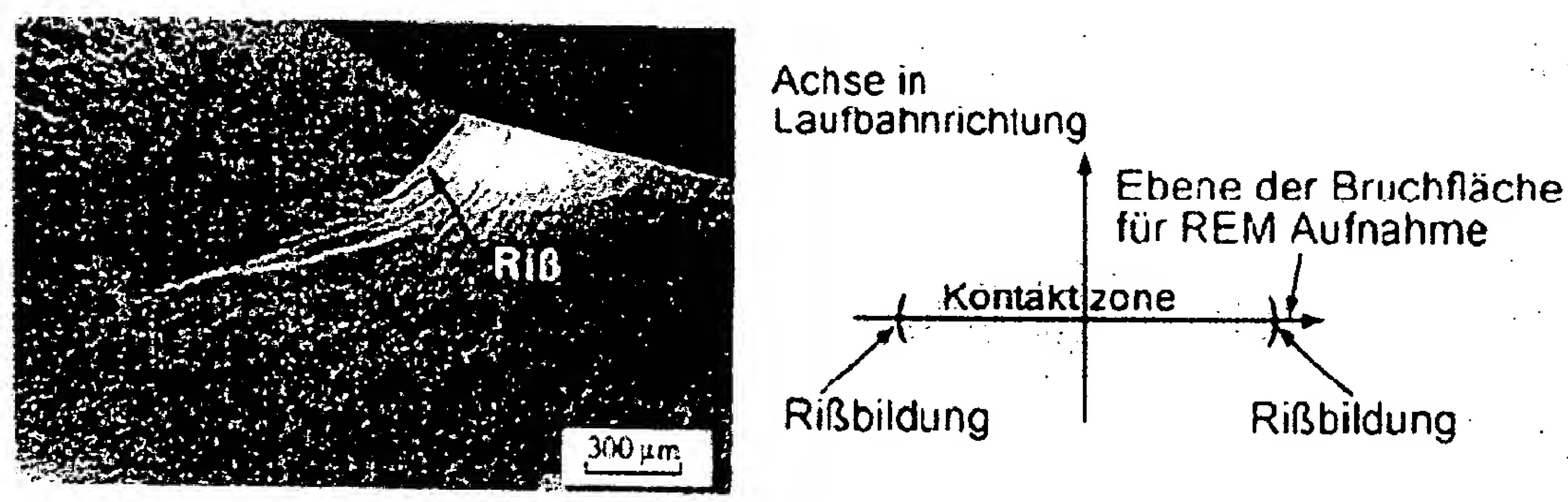

Bild 3: Kontaktzone und Lage der Risse im statischen Kugel-Laufringsegment-Kontakt

Das Rißbildungsverhalten im gleitenden Kugel-Platte-Kontakt kann untersucht werden, indem eine Kugel aus HIPSN gleitend über eine GPSN Platte bewegt wird. Die Normalkraft wird durch ein Gewicht vorgegeben, die Tangentialkraft wird gemessen. Die Experimente werden bei niedriger Gleitgeschwindigkeit (ca. 2 mm/sec) in Luft durchgeführt. Die Gleitspur mit einer Länge von ca. 10 mm wird dabei nur einmal von der Kugel überstrichen. Für einen Kugelradius von 2,38 mm treten ab 15 N Normalkraft und bei einer Tangentialkraft von 9 N erstmals Risse in der Gleitspur auf. Trotz der kurzen, einmalig beanspruchten Gleitstrecke, lassen sich tribochemische Effekte nicht gänzlich vermeiden. In der Laufspur bilden sich Schichten, die möglicherweise aus amorphem SiO_2 aufgebaut sind.

Der statische und der gleitende Kugel-Platte-Kontakt bilden die Grundlage für die Entwicklung eines bruchmechanischen Modells zur Beschreibung des mechanischen Versagensverhaltens keramischer Werkstoffe unter hohen Kontaktbeanspruchungen.

3. Wälzverschleißuntersuchungen

Eine Bindeglied zwischen den oben dargestellten Untersuchungen zur Tragfähigkeit und Rißbildung im statischen bzw. gleitenden Belastungsfall und den lebensdauerbeeinflussenden Prozessen im realen Wälzlager stellen Wälzverschleißexperimente mit geometrisch einfachen Wälzkörpern dar. In Prüfständen, z.B. nach dem sog. "Amsler-Prinzip", werden zwei zylindrische Proben mit definierter Normalkraft und Schlupf aufeinander abgerollt. Eine der Proben ist zur Erzeugung definierter Kontaktbedingungen ballig ausgeführt. Der Bearbeitungszustand beider Proben entspricht dem der Wälzlagerlaufringe.

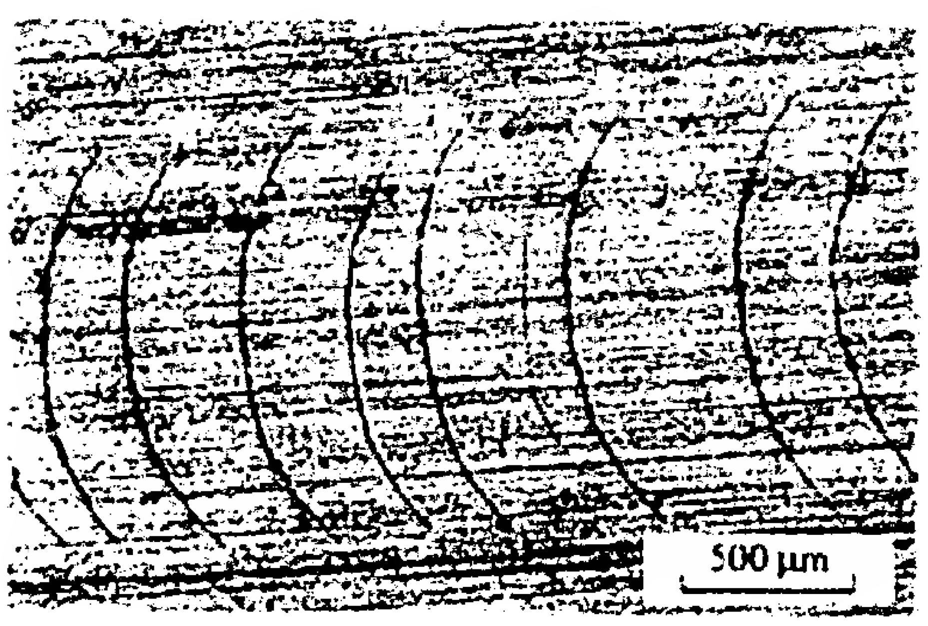

Bild 4: Rißbildung nach 500 Umdrehungen

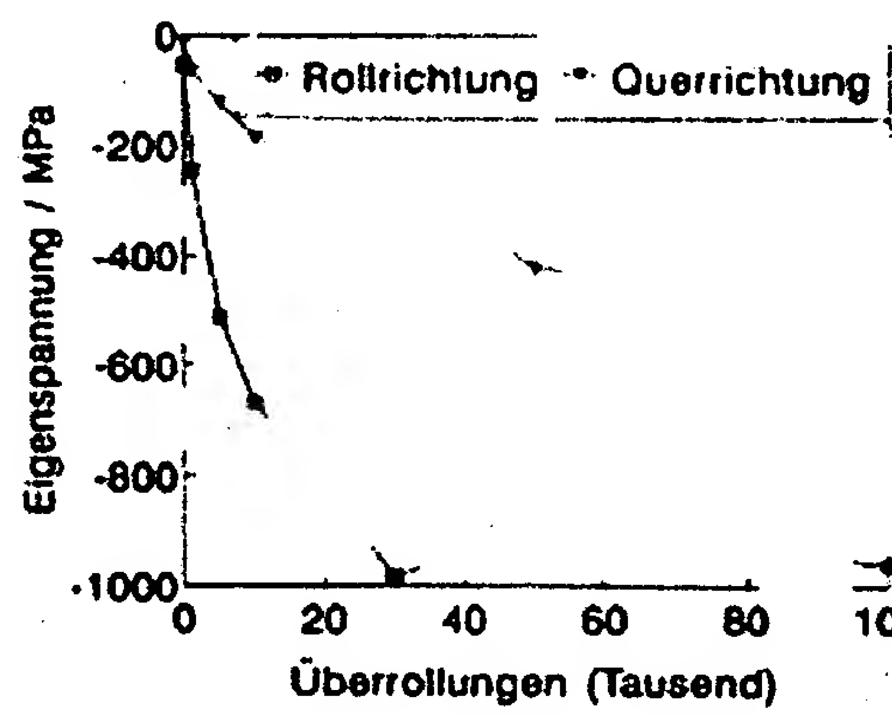

Bild 5: Röntgenographisch ermittelte Eigenspannungen

Bild 4 zeigt für eine unter 3 GPa Hertzscher Pressung und 3 % Schlupf geprüften Probe, daß erste Rißbildung schon in einem sehr frühen Stadium auftritt. Daß diese Rißbildung, die bereits bei 500 Umdrehungen beginnt, auch nach 50000 Überrollungen nicht zum katastrophalen Versagen führt, kann durch die "Stützwirkung" der sich entwickelnden, hohen Druckeigenspannungen erklärt werden. Bild 5 zeigt, daß sich in oberflächennahen Bereichen sehr schnell sehr hohe Druckeigenspannungen ausbilden, die in Rollrichtung bis zu 1 GPa, quer zur Rollrichtung bis zu 0,5 GPa erreichen. Wie bei der Hartbearbeitung (Schleifen, Läppen) von Keramik /3/, werden offensichtlich auch bei Wälzbeanspruchung des spröden Werkstoffs Keramik mikro- und makroskopische Verformungen hervorgerufen, die außerordentlich hohe Eigenspannungen zur Folge haben können. Daraus leiten sich die guten

Notlaufeigenschaften unter hohen mechanischen Beanspruchungen, z.B. in Trockenlaufphasen, ab.

4. Bruchmechanische Modellierung des Versagensverhaltens

4.1 Ersatzfehlermodell

Keramische Werkstoffe versagen ausgehend von Fehlerstellen wie Poren, Einschlüssen oder Mikrorissen. Die an den Fehlerstellen auftretenden lokalen Spannungsüberhöhungen können nicht durch plastische Verformung abgebaut werden. Dies führt bei genügend hoher Belastung zu Rißwachstum und zum Versagen durch Sprödbruch. Die an Rissen auftretende Beanspruchungssituation können für keramische Werkstoffe gut mit den Methoden der linear elastischen Bruchmechanik (LEBM) beschrieben werden. Das zur Modellierung des Sprödbruchverhaltens unter Kontaktbeanspruchung entwickelte Ersatzfehlermodell ist folgendermaßen aufgebaut: Zunächst werden aus den Geometrie-, Belastungs- und Werkstoffdaten die Kontaktzonengröße und die Kontaktspannungsverteilung berechnet. Hierfür existieren meist analytische Näherungslösungen. Im Gegensatz dazu liegen für den Spannungszustand im Volumen meist keine geschlossenen analytischen Lösungen vor. Die Kontaktspannungen werden durch eine Überlagerung von Punktkräften ersetzt und die analytisch darstellbaren Punktlösungen numerisch zum Gesamtspannungsfeld superpositioniert. Schließlich wird ein halbkreisförmiger Oberflächenriß zur Modellierung einer natürlichen Fehlerstelle in einem der Kontaktkörper angenommen. Da in keramischen Bauteilen die Fehlerstellen statistisch verteilt sind, wird im Modell die Lage des Risses so lange verändert, bis die maximale Beanspruchung erreicht wird. Rißwachstum tritt dann ein, wenn der Spannungsintensitätsfaktor

$$K_I = \sigma \sqrt{\pi a}\ f(\text{Geometrie}) \qquad (2)$$

(σ = Spannung, a = Rißgröße) eine kritische Größe, die Rißzähigkeit K_{Ic}, überschreitet; ausführlich ist dies in /2/ beschrieben..

4.2 Modellierung der experimentellen Ergebnisse

Neben den experimentellen Ergebnissen der Kugel-Platte-Druckversuche sind in Bild 2 die vom Modell vorhergesagten Kräfte für Rißwachstum eingezeichnet. Die in das Modell eingehenden Parameter sind E = 300 GPa, ν = 0,28, K_{Ic} = 4,2 MPa$\sqrt{m}$ und der Radius des Oberflächenrisses a = 15 µm. Die Vorhersagen des Modells stimmen gut mit den experimentellen Ergebnissen überein. Bei kleinen Kugelradien ist jedoch eine systematische Abweichung zu erkennen. Der Grund dafür liegt in der plastischen Verformung, die bei kleinen Kugelradien der Rißbildung vorausgeht. Die plastische Verformung führt zu einer Reduktion

der Zugspannungen, die im Experiment durch eine erhöhte Druckkraft ausgeglichen werden muß.

Im gleitenden Kugel-Platte-Kontakt kommt es bei einem Kugelradius von 2,38 mm, einer Normalkraft von 15 N und einem Gleitreibungskoeffizienten von 0,6 zu Rißbildung. Bei einer Normalkraft von 10 N sind dagegen noch keine Risse auffindbar. Das Ersatzfehlermodell berechnet für 10 N einen Beanspruchungszustand, für den $K_I < K_{Ic}$ gilt (Rißwachstum findet nicht statt), während für 15 N Normalkraft das Rißwachstumskriterium $K_I > K_{Ic}$ erfüllt ist. Trotz der in diesem Experiment überlagerten tribochemischen Effekte (Schichtbildung) gelingt es also, die Rißbildung mit dem bruchmechanischen Modell zu beschreiben.

Im statischen Kugel-Laufring-Experiment überschätzt das Modell die experimentell ermittelte Tragfähigkeit. K_I erreicht bei der Normalkraft von 9 kN, bei der 50 % aller Ringe einen Riß zeigen, nicht den Wert von K_{IC}. Dies kann auf die bei diesen hohen Lasten entstehenden, großen Kontaktzonen zurückgeführt werden. Bei 9 kN Normalkraft wird eine Hertzsche Pressung von ca. 7,5 GPa und eine Kontaktzonenbreite von ca. 2 mm erreicht. Die Kontaktzone erreicht damit Bereiche der Laufrinne, die leichte Formabweichungen aufweisen können. Dies führt zu lokalen Spannungsüberhöhungen und damit zum vorzeitigen Bruch.

4.3 Kugellagermodellsystem

Das Kugellagermodellsystem ist aus einer im Halbraum eingebrachten Rinne mit den Radien R_B und R_L und einer unter der Normalkraft F rollenden Kugel mit Radius R_K aufgebaut. Der halbkreisförmige Oberflächenriß liegt senkrecht zur Rollrichtung und senkrecht zur Oberfläche der Laufrinne.

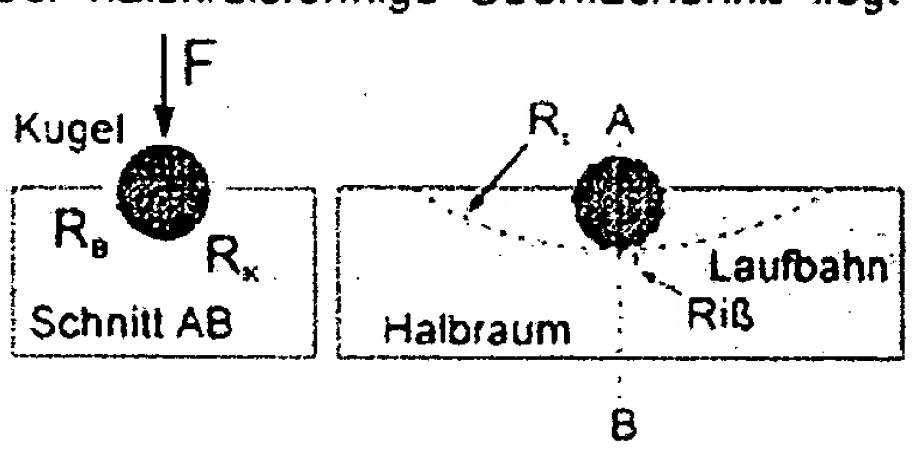

Bild 6: Kugellagermodellsystem

Bild 6 zeigt das Modellsystem. Um eine konservative Abschätzung der nachfolgend berechneten Tragfähigkeiten zu geben, wird die Anfangsfehlergröße zu 40 Mikrometer angenommen und der entlang der Rißfront maximale Spannungsintensitätsfaktor an der Oberfläche des Bauteils betrachtet. Übersteigt dieser Wert den Materialparameter K_{Ic}, so ist die Tragfähigkeit überschritten. Plastische Verformung tritt dann auf, wenn die maximale Vergleichsspannung nach von Mises den Wert Fließspannung Y von 6300 MPa überschreitet. Näherungsweise ist die maximale Vergleichsspannung unabhängig von der Kontaktzonengeometrie /4/ und für den statischen Lastfall gilt der Zusammenhang, daß für $p_0 > 1,6$ Y plastische Verformung einsetzt.

4.4 Auslegungskurven für statischen und rollenden Kontakt

Die auf der Basis der vorgestellten Versuche und Modelle abgeleiteten, im folgenden diskutierten Auslegungskurven, sind für ein Kugellagermodellsystem mit den in Tabelle 2 aufgeführten Geometrie- und Werkstoffdaten berechnet.

E - Modul	ν	K_{Ic}	Y	R_K	R_B	R_L
300 GPa	0,28	4,2 MPa√m	6300 MPa	3,171 mm	3,23 ... 3,36 mm	23 mm

Tabelle 2: Modell- und Materialparameter für Kugellagermodellsystem

Statischer Lastfall

In Bild 7 sind die maximale Zugspannung im Lager bei Rißbildung und die zur Rißbildung und plastischen Verformung notwendigen Hertzschen Pressungen als Funktion der Schmiegung (R_B/R_K) eingetragen. In Bereichen kleiner Schmiegung setzt plastische Verformung vor Rißbildung ein. Oberhalb einer Schmiegung von ca. 1,022 tritt Rißbildung vor plastischer Verformung auf. Die statische Tragfähigkeit (Einsatzgebiet in Bild 7) nimmt insgesamt mit zunehmender Schmiegung ab. Zum Erreichen hoher Tragfähigkeitswerte muß allerdings eine hohe Formgenauigkeit der Lagerlaufrinnen gewährleistet sein /5/.

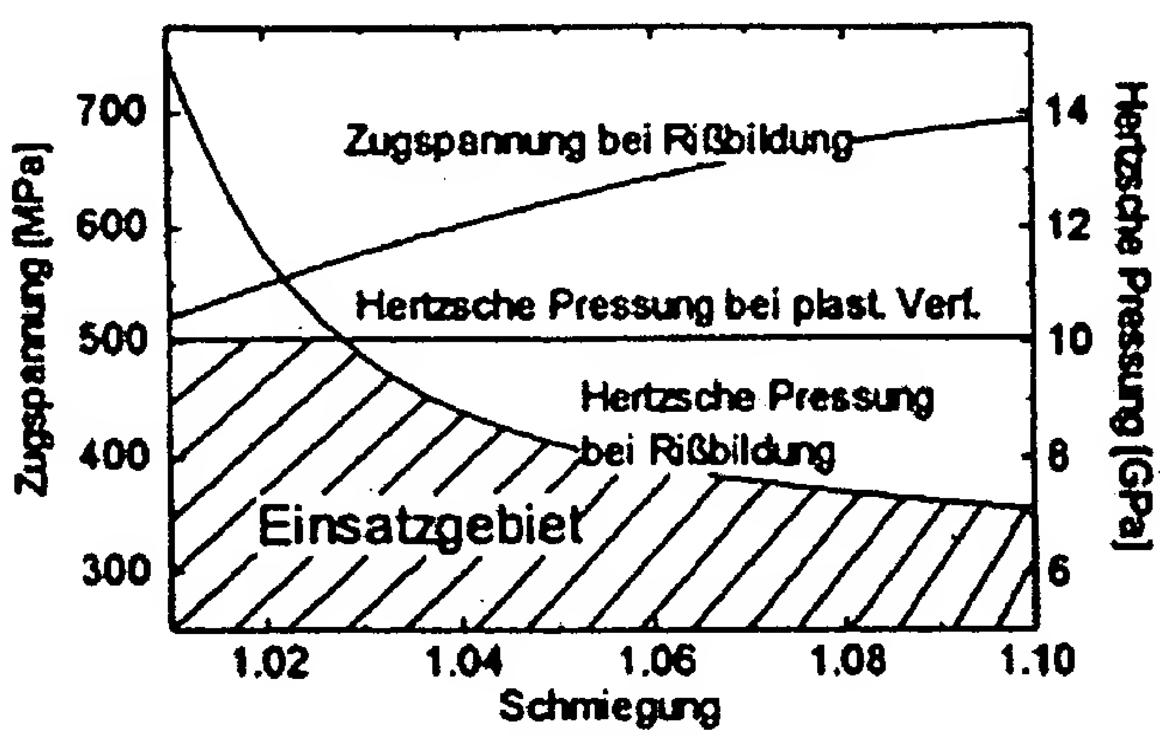

Bild 7: Zugspannung bei Rißbildung und Hertzsche Pressung bei Rißbildung und plastischer Verformung als Funktion der Schmiegung

Dynamischer Lastfall

Unter dem dynamischen Lastfall, bei dem die Gleitreibungszahl berücksichtigt werden muß, wird die Beanspruchung durch eine rollende Kugel verstanden. Die Betrachtung wird für zwei unterschiedliche Gleitreibungszahlen von 0,3 (Feststoffschmierung) und 0,6 (Trockenlauf) durchgeführt. Bild 8 zeigt die zur Rißbildung notwendige Kraft $F_{Riß}$ als Funktion der Schmiegung für die beiden Gleitreibungszahlen. Bei der kleineren Gleitreibungszahl wird erwartungsgemäß insgesamt eine größere Tragfähigkeit erreicht. Bei einer Gleitreibungszahl von 0,6 ist eine weitere Schmiegung, bei einer Gleitreibungszahl von 0,3 eine engere Schmiegung von Vorteil.

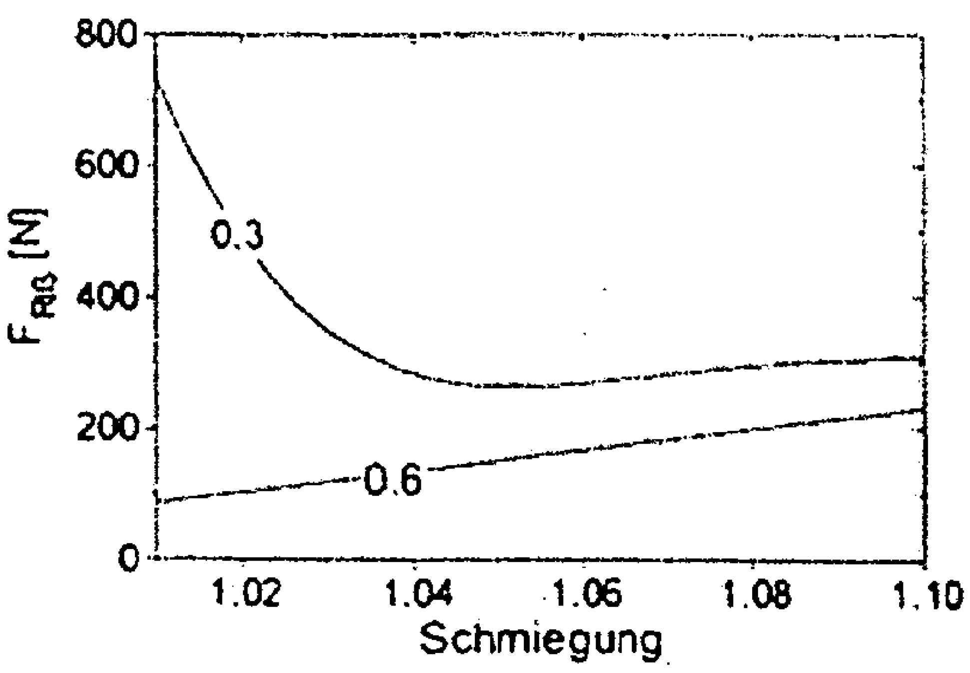

Bild 8: $F_{Riß}$ für den dynamischen Lastfall für Gleitreibungszahlen von 0,3 und 0,6.

5. Zusammenfassung und Ausblick

Vollkeramische Wälzlager eröffnen der Lagertechnik neue Möglichkeiten. Insbesondere unter aggressiven Umgebungsmedien, bei hohen Temperaturen und im Trockenlauf überzeugt der Werkstoff Keramik durch ein hervorragendes Eigenschaftsprofil. Der industrielle Einsatz vollkeramischer Wälzlager erfordert Auslegungskriterien, Lebensdauerabschätzungen und Aussagen zur Zuverlässigkeit. Die Erkenntnisse aus dem Bereich der metallischen Lager können aufgrund der völlig unterschiedlichen Werkstoffeigenschaften nicht auf das keramische Lager übertragen werden. Aus diesem Grund wurden zunächst die Versagensmechanismen in lagerähnlichen Systemen (Kugel-Platte Druckversuch, Kugel-Laufring-Druckversuch) untersucht. Innerhalb eines bruchmechanischen Modells gelingt die Beschreibung der auftretenden Rißbildung. Auf dieser Basis können für ein Kugellagermodellsystem Aussagen zur statischen und dynamischen Tragfähigkeit gemacht werden, wobei insbesondere der Schmiegung der Lager besondere Bedeutung zukommt. Im Gegensatz zu metallischen Lagern ist für das Versagensverhalten keramischer Lager in erster Linie nicht die plastische Verformung (und damit die Höhe der Vergleichsspannung, z.B. nach von Mises), sondern vielmehr die Höhe der Zugspannungen von Bedeutung. Dies hat zur Folge, daß das Optimum der Schmiegung von der Gleitreibungszahl abhängt. Zur Steigerung der Notlaufeigenschaften bei Mangelschmierung oder Trockenlauf kann durch eine keramikgerechte Wahl der Schmiegung eine bedeutende Steigerung der Tragfähigkeit erreicht werden.

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